University of Massachusetts Amherst
ScholarWorks@UMass Amherst

Landscape Architecture & Regional Planning Masters Projects | Landscape Architecture & Regional Planning

2-2011

A Methodology to Measure Emissions Generated by Automobile Trips to Schools Participating in Safe Routes to School

Joshua C. Rickman
University of Massachusetts - Amherst, jrickman@PVPC.org

Follow this and additional works at: https://scholarworks.umass.edu/larp_ms_projects

Part of the Urban Studies and Planning Commons

Rickman, Joshua C., "A Methodology to Measure Emissions Generated by Automobile Trips to Schools Participating in Safe Routes to School" (2011). *Landscape Architecture & Regional Planning Masters Projects*. 28.
Retrieved from https://scholarworks.umass.edu/larp_ms_projects/28

This Article is brought to you for free and open access by the Landscape Architecture & Regional Planning at ScholarWorks@UMass Amherst. It has been accepted for inclusion in Landscape Architecture & Regional Planning Masters Projects by an authorized administrator of ScholarWorks@UMass Amherst. For more information, please contact scholarworks@library.umass.edu.

A Methodology to Measure Emissions Generated by Automobile Trips to Schools Participating in Safe Routes to School

A Project Presented

by

Joshua C. Rickman

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

Masters of Regional Planning

August 2010

Landscape Architecture and Regional Planning

© Copyright by Joshua C Rickman 2010

All Rights Reserved

A Methodology to Measure Emissions Generated by Automobile Trips to Schools Participating in Safe Routes to School

A Project Presented

by

Joshua C. Rickman

Approved as to style and content by:

Dr. Elisabeth M. Hamin, Chair

Dr. John Collura, Co-Chair

Dr. Mark Hamin, Department Head of Landscape Architecture and Regional Planning

DEDICATION

To Mom, Dad, Jason, Heidi, Earl, Kim, Wesley, Andre, Ryan and my friends of Sudbury and Hudson Massachusetts. Your support, guidance and love have been my lifeblood the last 22 years of my education.

"The environment suggests distinctions and relations, and the observer- with great adaptability and in the light of his own purpose-selects, organizes, and endows with meaning what he sees."-Kevin Lynch

ACKNOWLEDGMENTS

I would like to thank my advisors Dr. Elisabeth Hamin and Dr. John Collura for their support and guidance throughout this endeavor; and the Department of Landscape Architecture and Regional Planning for its permission to carry out this research. Furthermore, I would like to thank Principal MaClean of Southampton Road Elementary School and the Westfield Public School System for all their support and permission to carry out this research.

ABSTRACT

Vehicular emissions in close proximity to schools can have detrimental health effects on children. The Safe Routes to School program claims to improve air quality through implementation due to reduced volume of traffic generated to schools. While a reduced volume of traffic may reduce the amount of emitted pollutants, the program lacks the ability to quantitatively track this air quality improvement. A school participating in the Safe Routes to School program was selected based off of health risks associated with a high vehicular volume and the proximity of that traffic to the school. A survey was utilized to generate a vehicle inventory of faculty and parent drivers of this school. The inventory was applied to EPA equations to demonstrate the amount of emissions generated on a daily, weekly, monthly and school year basis. The equation was successful in generating quantitative data that demonstrate the total emissions generated by the school. This equation can establish pre emission levels versus post emissions levels. This comparison demonstrates the effect the program has on reducing emission levels of traffic generated to the school. Once applied on a larger scale, trends and applicability of the program in different regions, demographic areas and community types (rural, suburban and urban) can be identified. This identification will enable Safe Routes to School users to invest in individual initiatives that have been successful in similar areas.

A Methodology to Measure Emissions Generated by Automobile Trips to Schools Participating in Safe Routes to School

Winter 2010

Joshua Calaway Rickman, B.S., Westfield State College

M.S., University of Massachusetts-Amherst

Directed by: Dr. Elisabeth Hamin and Dr. John Collura

List of Tables

List of Figures

CHAPTER 1

Introduction

Safe Routes to School Goals and Challenges

Safe Routes to School Program is a Federal program to improve the health of children by enabling walking and bicycling to school. The program is funded under Safe, Accountable, Flexible, Efficient, Transportation Equity Act a Legacy for Users Act (SAFETY-LU), and was awarded $612 million dollars from 2005-2009[1]. States have individual Safe Routes to School coordinators who help administer and assist with these projects. Most projects can receive additional funds from the state and local sources.

Safe Routes to School has three major goals which are to decrease obesity of the student population, increase safety for children to walking or biking to school and lastly to improve the air quality for children and teachers attending schools. The main route to achieving these goals is to, most often through the construction of sidewalks, thereby enabling children to walk or bike to school. For the first goal of decreasing student obesity, the logic is unimpeachable, but there are no studies to date that actually prove the connection between this specific program and childhood obesity. Their second goal is to increase the safety of the roadways that children's and parents use to access the schools. As will be described in the next section, there are studies that demonstrate the relationship between prescribed traffic improvements (usually sidewalks) and actual increased safety. Their last claim is an improvement in air quality, which is inferred by an increase in more children walking or biking to school. There are very few resources or tools developed to understand the actual improvements in air quality for the school. This research seeks specifically to contribute to knowledge about this third goal, improved air quality.

CHAPTER 2

Literature Review

Schools and Emissions

Suburban form has promoted children's' dependency on parents being the sole providers of transportation to various activities. The suburbs are sprawling which increases the amount of distance many individuals are required to travel each day. In classic construction of suburban sprawl, uses of land are carefully segregated. Zoning regulations have created new communities where families moving in have only one mode choice--the automobile--to reach the "big box" stores, parks, and schools[2]. The result is that "sprawl consists of the miles of pavement that are necessary to connect the four disassociated (residential, office and business parks, shopping centers, civic) components. Since each piece of suburbia serves only one type of activity, and since daily life involves a wide variety of activities, the residents of suburbia spend an unprecedented amount of time and money moving from one place to the next.[3]" The outcome of these types of zoning practices along with lifestyle choices is that Americans are now driving 88 percent farther than they did in 1969 to go shopping and an overwhelming 137 percent farther to accomplish family and personal errands[4].

Safe Routes to Schools claims that 20 to 30 percent of morning traffic is caused by parents driving their children to school[5]. Within each community, schools are typically one of the highest trip generators. Trip generation is a model that quantifies the amount of traffic that would each use or zone of the town would attract.

Parents do not feel safe allowing their children to bike or walk to school due to lack of sidewalks and safe crossing opportunities. Federal funding in safe routes to school requires that 70-90 percent funds be spent on the infrastructure (sidewalks, bike lanes, trails, well marked intersections, traffic calming) within two miles of the school[6]. This two mile requirement for infrastructure investment only enhances the area in direct proximity to the school which creates a smaller critical mass of kids and parents walking and biking. "Certain development patterns, such as a lack of sidewalks, long distances to schools, and the need to cross busy streets, discourage walking and biking to school. Eliminating such barriers can increase rates of active commuting[7], where active commuting is defined as non-motorized modes (walking, biking).

Beyond the immediate health benefits of exercise, reductions in automobile travel to schools have an air quality benefit that also positively impacts health. The school creates a nucleus of travel, and the many vehicles commuting to the school emits pollutants into the local environment, which can affect children's health. Providing an environment with reduced emissions around school zones is important for proper children's' health development. Lung development of children can be damaged when the individual is subjected to exposure of higher level of air pollution and emissions. Furthermore, children are naturally at a higher risk of receiving negative effects from air pollution, largely due to their natural lack of lung development and lack of natural defenses from these inhaled pollutants[8]. Children also have a higher metabolic rate. This increased rate results in more breaths per minute which means an increased airway exposure to the surrounding elements in the local environment[9]. If schools are located near major roadways or are exposed to pollutants, the schoolchildren will breathe in those air borne chemicals at a higher rate of speed.

Research on the correlation between children's' health and proximity to roads began in the later half of the 1990's[10][11]. This research specifically connected respiratory health issues, such as asthma with major roadways. Further research has shown that children who live in areas with higher traffic volumes have been found to be more susceptible in having bronchitis symptoms and physician diagnosed asthma[12]. "Alternatively, repeated daily exposures for 6–8 hours during the school year may themselves represent biologically important influences on some children's respiratory health, analogous to occupational exposures for susceptible adults[13]." Repeated daily exposure at schools can be dangerous for health development of a child, limiting their exposure to emissions is important.

While complete effects and measurements of emissions and children's' health are still being developed, there is strong data that indicates a negative relationship between children's' health and their proximity to high volume roads[14 15 16].

School proximity to major flows of traffic is a decisive variable in reducing exposure to these harmful air borne pollutants. Exhaust is most concentrated near the roadway itself; the pollutant decreases exponentially as the distance from the roadway grows[17]. Studies have found that 150 meters is the distance from the point of the exhaust emission to persons at which health effects appear to be minimal[18]. Many schools do not achieve this distance, however. In a study analyzing the exposure of public schools to major roadways, researchers found that in the nine Metropolitan Statistical Area 10% of schools were located within 100 m, and 30% within 400m[19]. The importance of correcting this for new school sitings this has been recognized in policy. The EPA School Siting Guidelines recognizes this distance 150 m, and where possible recommends a further distance as a best management practice. Emissions reduction may be a passive approach to increasing the health of children, but is an important part of helping children to attain optimal health potential.

A Quick Review of the Science of Emissions

Emissions from automobiles occur in the troposphere which is the lowest atmospheric region, the one that possesses cities, towns, roads, and most human activities[20]. The troposphere extends from the earth up 8 to 14.5 km (dependent on season), to the tropopause. Almost all weather occurs in this part of the atmosphere[21]. VOC's, CO2 and NOx, are all emitted from vehicles which lead to complex interactions between these chemical compounds often resulting in the creation of ozone. Ozone is created at the ground level by a reaction between NOx and VOC's in the presence of sunlight. The harm of this chemical reaction depends on its location within the atmosphere[22]. "Ozone is known to have adverse on health, vegetation and materials[23]." Ozone is naturally occurring the upper levels of the atmosphere which creates earth's atmosphere; however human activity of industry and transport in the troposphere produces ozone pollution commonly seen as smog. The chemistry of the atmosphere is pollution commonly seen as smog. The chemistry of the atmosphere is very fragile, many pollutants that are created by human activity have detrimental effects on the atmospheric processes and reactions. The creation of ozone and other gases have been found to contribute to acid rain, ozone depletion, and global warming.

"The troposphere is well-mixed and its composition is 78% N2, 21% O2, 1% Ar, 0.036% CO2, varying amounts of water vapor depending on altitude and temperature, and minute amounts of a number of trace gases[23]". Introduction of CO2, NOx, and VOC's directly impact this chemical composition of the troposphere, which is subjected to vertical mixing. "Vertical mixing often takes place in the lower stratospheric layers. Cold air displaces warm air. As the cold air has a higher density and is heavier (according to the general gas law), the warm air is pushed up steeply and large portions of the troposphere in the North-Atlantic, and even the lower stratosphere, are mixed[24]." This vertical mixing allows pollutants to be introduced into the atmosphere. However "…a temperature inversion acts to limit the vertical mixing of pollutants, which allows concentrations to build[25]." This temperature inversion occurs when a pocket of warm air is layered above a pocket of cool air. Nocturnal inversions are the most common, where the air near the ground stays cooler the air in the upper troposphere. This traps emissions closer to the ground, but the emissions are typically mixed vertically once the ultra violet rays have been introduced during the morning period[26].

Three pollutants most commonly related to automobile pollutants are Volatile organic Compounds (VOC's), Nitrogen Oxides (NOx), Carbon Monoxide (CO) and Carbon Dioxide (CO2). These pollutants are produced during the combustion process of automobiles. The emitted pollutants are deposited into the local environment, which in turn affect the health of the children and people.

VOC's are produced by a variety of paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbon-less copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions[27]." VOC's are most prevalent indoors, the EPA has conducted many studies which demonstrate that the presence of VOC's is much higher indoor which has lead to health complications for those who were exposed to the pollutant. They are also created through the combustion process of the car and emitted through the tailpipe. Respiratory ailments, allergic reactions and decreased immunity have been associated with children who have been exposed to VOC's[28].

The carbon monoxide emissions process results in harmful health effects. Carbon monoxide elevates the concentration of Methane (CH4) in the atmosphere due to chemical reactions with hydroxyl and OH which would otherwise naturally combat the methane[29]. "When inhaled, carbon monoxide reacts very rapidly with hemoglobin in the blood, preventing uptake and transport of oxygen. Because carbon monoxide readily and firmly attaches to hemoglobin, it stays in the blood for a relatively long time. Thus, during an exposure carbon monoxide concentrations in blood can rise in a matter of minutes, then stay high for hours[30]." Carboxyhemoglobin (carbon monoxide and hemoglobin after chemical reaction) reduces the amount of oxygen that is provided to the organs within the body[31]. "Through natural processes in the atmosphere, it is eventually oxidized to CO2[32]."

The transportation sector is the second largest source of CO2 emissions in the U.S.... Automobiles and light-duty trucks account for almost two-thirds of emissions from the transportation sector and emissions have steadily grown since 1990[33]. Carbon dioxide has very similar health effects as carbon monoxide which mainly attacks the respiratory system. However, it also has some other effects such as headache, dizziness, nausea and other symptoms[34].

NOx represents seven compounds, the EPA only regulates nitrogen dioxide. "......(Nitrogen dioxide) is the most prevalent form of NOX in the atmosphere that is generated by anthropogenic activities[35]. The main anthropogenic activities producing N2O in the United States are agricultural soil management, fuel combustion in motor vehicles, nitric acid production, stationary fuel combustion, manure management, and adipic acid production[36]. "Nitric oxide reacts with oxygen in the air to produce nitrogen dioxide (NO2). Further oxidation during the day causes the nitrogen dioxide to form

NO2) are indirect and result from their role in promoting the formation of ozone in the troposphere....[39]." Nitrogen dioxide has multiple health impacts if subjected to long term exposure: emphysema, damage to respiratory tract, loss of ability to produce pathogens and weakened immune system[40].

Methods for Measuring Emission Factors

An emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant[41]. There are two main methods for estimating emission factors. 1) They can be generated from a vehicle emissions model such as the EPA MOBILE 6.2 or MOVES models. 2) Emission Factors can also be derived from speed Emission factors can be generated from a vehicle emission model such as MOBILE6, MOVES and EMFAC[42]. Mobile6 was the EPA's model used to test for air quality conformity in State Implementation Plans. "MOBILE6 is a computer program that estimates hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NOx), exhaust particulate matter (which consists of several components), tire wear particulate matter, brake wear particulate matter, sulfur dioxide (SO2), ammonia (NH3), six hazardous air pollutant (HAP), and carbon dioxide (CO2) emission factors for gasoline-fueled and diesel highway motor vehicles, and for certain specialized vehicles such as natural-gas-fueled or electric vehicles that may replace them[43]." Mobile 6.2 was limited by its lack of specificity. "This means that Mobile 6.2 does not have the ability to predict emission factors for a specific vehicle operating at a specific location at a specific time[44]." Furthermore the model has a limited ability to capture data from a small change in the transportation network. In 2010 it has been replaced by the new EPA MOVES model. "In the modeling process(for MOVES), the user specifies vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types to be modeled. The model then performs a series of calculations, which have been carefully developed to accurately reflect vehicle operating processes, such as cold start or extended idle, and provide estimates of bulk emissions or emission rates[45]." The MOVES model is now used to test for conformity with air quality regulations.

The second method to establish emission factors can be derived from a speed-emissions curve, tables or equations[46]. A speed emissions curve graphs a given vehicles driving speed and the correlating rates of specific emissions. "The impact of speed on engine efficiency is a non-linear relationship, with disproportionately greater impacts as traveling speed moves further away from the optimum level of around 50mph[47]." An example of a speed-emissions curve can be seen in figure-1 in appendix. Emissions tables typically assign vehicles to a certain vehicle type such as passenger car, light duty trucks and heavy duty vehicles. Once categorized the vehicle is assigned the given emission rate for the year it was produced. This categorization allows for accurate estimation of vehicle emissions. These tables have been used to develop emission output guidelines for state inspections of motor vehicles and the California Air Resource board has used it to evaluate Congestion Mitigation and Air Quality Improvement (CMAQ) Projects that occur within the state. Equations can also be used to estimate emission factors. Typical variables needed in these equations include but are not limited to: distance of travel, speed of vehicle, vehicle classification, and number of trips made per day. These emission equations can be done for specific pollutants as can be seen in Figure-1. This equation was developed for the American Bus Association in 2007[48]. The focus of this equation was to calculate the Carbon Dioxide emissions of passengers on a bus. Establishing the amount of CO2 emitted per passenger mile by vehicle type demonstrates the efficiency of certain modes to move people.

These methods can be used independently or combined to establish emission factors. This combination of methods is critical to the development of emission models. These computer based models require inputs from tables, equations and graphs. Emission factors are constantly improving due to technological advancement, and growing interest of pollutant production and effects.

The Safe Routes to School Program

The Safe Routes to School program was established in 2005 under section 1404 under models require inputs from tables, equations and graphs. Emission factors are constantly improving due to technological advancement, and growing interest of pollutant production and effects.

The Safe Routes to School Program

The Safe Routes to School program was established in 2005 under section 1404 under SAFETY-Lu. The safe routes program was awarded $612 million dollars from 2005 to 2009. Funds are awarded through states Department of Transportation then to individual schools. Each state is required to have a Safe Routes to School Coordinator, develop a Safe Routes to School program, and disperse funds equitably and in accordance with federal policies and laws[44]. "The purpose of this funding is to allow and encourage more children to safely walk and bicycle to school. The bulk(70 to 90%) of these grants allow schools and communities to retrofit and build roads, sidewalks, bike lanes and pathways to allow children to more safely walk and bicycle to school. A smaller percentage of funding (10 to 30%) supports non-infrastructure activities, including walking and bicycling safety education, driver awareness campaigns, more robust enforcement of speed limits and traffic safety rules, promotional events to encourage more children to walk and bicycle, and more[45]." More schools apply every year, the available funds can only aid a small percent of these projects. Simply, the demand for this program outweighs the available federal funds given to the states. Some states and local towns have created and allocated additional sources of revenue by involving the program into the annual operating budgets or by inclusion into the capital improvements projects plan. Private funds have been generated by corporations or businesses in the community, foundations and grants, individuals, events, and parent teacher associations. These private funds are generated through a shared interest in the improvements and conditions of the community. These funds are used directly to accomplish the safe routes to schools goals of increased safety, reduced obesity and improved air quality.

Safe routes to schools claims of air quality improvements are typically based on increased rates of alternative modes of travel and elimination of automobile trips to school[46]. Increased number of initiatives can not evaluate their contribution to the improvement of air quality. Safe Routes to school programs have a clear need for implementation of a system to quantify the improvements made to air quality. In "a recent Governments Accountability Office report on the SRTS program called for evaluating the program rigorously across a range of out comes including "safety, benefits, behavior changes,...improved student health, improved air quality, decreased traffic congestion and others[52]. The program has demonstrated its abilities and popularity, but requires improvements to the statistical data on its air quality improvement claims.

One of these current initiatives to decrease the amount of parents driving is the walking school bus. The walking school bus allows groups of students to be accompanied by one or more adults when traveling to school. There is a wide range of organization for this walking school bus, it can be formal school generated system or a parent driven program where families walk together. The flexibility and ease of the program has made it one of the most successful initiatives for Safe Routes to School. Safe Routes to School claims that the walking school bus accomplishes all of its goals, parental supervision leads to increased safety, walking to school increases student activity, and reduces the number of students reliant on motorized vehicles which improves air quality. The current evaluation does not include any questions on air quality improvements(see evaluation form figure-2 in the appendix). However, respondents are requested to answer questions on safety and physical activity improvements by the walking school bus. The evaluation of air quality improvement lacks input from the parents and children of the participating school. Air quality is a difficult topic, and requires more detailed knowledge than safety or activity level. Air quality is challenging to evaluate due to the lack of perceived impact. Lack of safety and obesity are obvious problems, pollutants lacks this visibility component. The walking school bus has inspired a similiar concept of bicycle trains. A bicycle train operates in a similar manner to walking school buses, a group of students are accompanied by adults to school but using their bicycles as a mode of transport. An adult is required to travel in front and is perceived impact. Lack of safety and obesity are obvious problems, pollutants lacks this visibility component. The walking school bus has inspired a similiar concept of bicycle trains. A bicycle train operates in a similar manner to walking school buses, a group of students are accompanied by adults to school but using their bicycles as a mode of transport. An adult is required to travel in front and is referred to as the train engineer, an adult is also in the rear and operates as the caboose. No current evaluation form on the Safe Routes to School.

The park and walk initiative provide an opportunity for parents and students to park in a central location then complete the trip to school on foot or bike. This idea was inspired by the concept of park and ride lots, where commuters park their vehicles in a lot and carpool or use transit to complete their trip. Schools that suffer from congestion issues can incorporate this initiative to reduce the number of motor vehicles in close proximity to the school. Typically these park and walk lots are used by families who live further away from school. As aforementioned, the funds are designated for infrastructure improvements within two miles of the school. Many school districts are much larger than 2 miles, and serve populations from greater distances. These park and walk lots are able to reduce the amount of emitted pollutants to the school zone specifically. Air pollution from roadways typically dissipates by 150 meters, and the majority of these park and walk lots are located further away than that distance. Presently there is no evaluation form for this initiative on the Safe Routes to School website.

Provision of alternatives modes of travel reduces automobile trips and correlating emitted pollutants to schools and communities. However, these air quality gains are ambiguous and lack any measurable improvement. Safe Routes to School must establish the ability to quantify the reduction of child exposure to motor vehicle emissions in order to continue the claim of air quality improvement. Their basic assumptions of improved air quality is correct, but lack impact and adequate evaluation methods unless the gains are quantifiable. This advancement is the natural progression Safe Routes to Schools needs for overall program improvement and justification.

Summary

This chapters broad outline of schools and emissions, atmospheric emissions, measurement of emissions, and safe routes to school program was necessary to identify current practices and demonstrate a need for advancement. The chapter began by outlining the current literature on school proximity to roadway traffic volumes. The process of atmospheric emissions demonstrated how pollutants operate and the harmful heatlh effects they have on respiratory systems. Methods of measurement were introduced to display current tools utilized to estimate emissions. Finally, a review of the Safe Routes to School program and emissions reduction initiatives. Research of these four areas is necessary for evaluating and creating a toll that is adequate and appropriate for the Safe Routes to School Program.

CHAPTER 3

Project Goal

Project Goal

To create a simple, easily applied methodology to quantify vehicular emissions generated by schools participating in the safe routes program. This method will quantify the pollutants of nitrogen oxide, carbon dioxide and volatile organic compounds, production of a typical trip to and from school for the respondent. The Safe Routes to School programs lack the ability to quantitatively demonstrate their initiatives improve the participating schools air quality. The study will initially establish the existing conditions of generated emissions, then will enable the school to track their individual progress in reduction.

Problem Statement

The Safe Routes to School program claims to help reduce vehicular emissions around school zones, but lacks supporting evidence or systems to monitor schools progress. The Safe Routes to Schools claims of obesity reduction and safety improvements have stronger evaluation and methods analysis. The intention of this research is to create a method to track Safe Routes to School's achievements in reducing the amount of emissions generated by motor vehicle trips. This method is purposely made user friendly for Safe Route to School administers or school faculty to implement and easily replicate. The tool will establish a baseline of what schools generate in motor vehicle emissions. The tool can receive new inputs once the program has been implemented and then the difference between baseline and post-implementation emissions will demonstrate the effectiveness of the program.

Research Question

What are the baseline emissions of Nitrogen Dioxide, Carbon Dioxide and Volatile Organic Compounds generated by vehicles traveling to the schools in the study?

Focused Research Question

How much emissions per day are generated by Parent driver/teachers?
How much emissions does an average parent driver produce?

How many parent drivers and teachers carpool?
How many cars are reduced by by carpooling?

How much emissions are saved by students who walk or bike to school?

Specific Objectives

1. Quantify the length of trip made by motor vehicles traveling to and from the school
2. Quantify and categorize the type and correlating?? total number of vehicles for each category
3. Average the length of trips for each category
4. Apply EPA model for school siting for motor vehicle emissions. This number will become the baseline emissions of school
5. Determine number of walkers and bikers. Represent savings of emissions

CHAPTER 4

Methodology

Introduction

This study analyzed the emissions generated at the Southampton Road Elementary School in Westfield, MA which participates in the Safe Routes to School program. Emissions generated is a concept which estimates the emissions created by individuals traveling to the school In order to calculate the amount of emissions generated by the school a voluntary five question survey was used to quantify and categorize these motor vehicle trips. This survey required information on vehicle types and if they carpooled in order to categorize the different groups. The survey required numerical values about average distance to school. These categories and numerical values acted as inputs when calculating emissions generated by the motor vehicles.

Generated Emissions

Emissions generated is a unique concept created for this study. This measure will establish how much CO2, NOx and VOC's are produced by vehicles traveling to school. Public schools have little control over volume that roadways in close proximity carry. The schools can only influence the behavior and volume of motorists that travel to the school. The school can easily quantify the total number of vehicles, type of vehicles, year of vehicles and access emission rates. Using this collected data as inputs emissions can be estimated to daily, weekly, monthly and yearly totals. While the generated emissions may not effect the school zone alone, and would rather be dispersed along the individual trip, the school should make efforts in reducing the automobile trips and correlating emissions they generate.

Survey

This voluntary survey was distributed by the Elementary school in each classroom. The full survey instrument can be seen in figure-3 in the appendix. Production and printing was paid by the researcher, no costs were placed onto Southampton Road Elementary School. The students brought home the survey to complete with their parents. Then returned and collected by the school. 450 surveys were distributed to the student and 50 surveys to the faculty. 84 surveys were returned by the students, and 21 surveys were returned by the faculty. The surveys responses produce a sample of the vehicular commuters of the individual school. This sample is important in extrapolating the pollutants of the total fleet as well as producing a typical commuter vehicle emitted pollutants. Furthermore, this sample enables daily, weekly, monthly and yearly prediction of anticipated pollutants.

Non-Response Bias

The sample produced through the survey was compared to the Massachusetts Department of Transportation, geographic information analysis and Census statistical information. The Registry of Motor Vehicles department is within the Massachusetts Department of Transportation. This department produces a report which calculates the percentage share of vehicles for both light duty trucks and passenger autos for each community. Additionally, these reports calculate the average age of vehicles for each community.

Vehicle Percentage Share

The State reported the percentage share of passenger vehicles and light duty trucks/suvs were 51.4% and 35.7% respectively. The survey results indicated that 67.6% of vehicles traveling to the school were passenger cars while the remaining 31.4% were SUV/Truck or Van. The reason for the discrepancy between the passenger car percentage share reported by the state versus the survey is the type of vehicles that schools generate. The states numbers include all registered vehicles, which includes trailers, heavy duty trucks, motorcycles. Inclusion of these vehicle types reduces the total percentage share of passenger vehicles. Heavy duty trucks, trailers and motorcycles are typically not a mode used to transport students to school. Passenger cars, Trucks, SUV's and Vans are the primary carriers of students to schools. The percentage share of SUV/Trucks and Vans had a 4.3% difference between the survey calculations and the states numbers.

Vehicle Average Age

The survey results indicated that the average passenger cars were 6 years old while the average SUV/Trucks and vans were 5 years old. According to the 2008 figures reported by the state, the average registered vehicle was 10 years old. This average age is double the survey predicted total for the vehicle types average age. This average age produced by the state does include all registered vehicles types, and is two years old. This prediction in the survey of more modern vehicles produces a more conservative emissions estimate for the school. This prediction is more conservative because it uses a 2005 vehicle emissions per mile rate for prediction which has lower emission rates than an older vehicles from 2000.

Average Distance to School

The distance traveled by students to the Southampton Road School averaged 3.5 miles. This distance is produced by totaling all parent drivers responses. The Westfield Public School Adminstration produced a list of all streets that the Southampton Road School serves. This list was used to create a road network. Overlaying this road network onto an orthographic image from MassGIS(Massachusetts GIS Inventory) displayed residential clusters and main intersects for less dense residential areas. Some residential clusters and neighborhoods are easy to identify in the Southampton School District service area. Major intersections for the neighborhoods were identified on the road network for these locations. This school also serves areas of the community that are less dense or rural. For these less dense locations a main intersect on the road network was identified that residents would use to access the school. A shortest path tool was then used to calculate the least segment lengths needed to travel to the school from these identified residential clusters and main intersects. The distance for these 6 identified residential clusters and main intersects averaged 3.2 miles. Table 1 in the appendix identifies identifies the selected locations and correlating distances.

Carpooling

According to the 2000 decennial census 5.4% of Westfield residents carpooled to work with a truck, van, suv or passenger car. Of the 105 surveys 3 reported to carpool or 2.8% of respondents. Westfield does not have a large carpooling population, and the survey indicated even less participation. The low share of carpooling calculated by the survey reflects the low percentage produced in the 2000 survey.

Emissions

The emissions per mile was generated through the EPA Mobile 6.2 program. This program calculates emissions of hydrocarbons, nitrogen oxide, and carbon dioxide for different vehicle classes (Ire. motorcycle, passenger car, truck). The program is typically used in State Implementation plans when addressing federal Clean Air Act Standards. One function of Mobile 6.2 is to generate emissions per mile. These emissions per mile outputs are produced by the Massachusetts Department of Transportation. To increase replicability, the Mobile 6.2 program will use these EPA numbers, which will (enable individual users to use the software without needing additional training) avoid individual users needing to learn and run the Mobile 6.2 software.

Emission Models

Once the survey has been analyzed and the Mobile 6.2 emissions per mile have been determined these quantities and categories can be inputted into the EPA's School Siting Calculation. This school siting equation seen in figure-1 will be used to determine the amount of emissions generated by motor vehicle trips to or from the school. While the EPA will apply to the school as a whole, this particular method will apply the equation to each transportation mode and the population of users of that specific mode of travel(Figure-2). The equation will be done separately for parent drivers, teachers and the school buses to demonstrate each groups emissions to the school. The data will also be broken down further by vehicle type (to illustrate the difference in emissions per mile) due to the difference in emissions per mile. The equation first requires that emissions per trip be established. The frequency required for that trip can be applied and summed with other inputs to calculate the totals. School bus emissions differ greatly from a passenger car, applying the same emissions per mile would lead to erroneous results.

Figure 1-EPA School Siting Calculation

Enrollment * auto mode split * average trip length * emissions/mile * 2 trips/day = emissions/day-for a car

Figure 2-Equation Used for Study

(Emissions/mile * Trip Length (in miles)) * Frequency of Trips = emissions per chosen frequency

Site Location

The school that will be assessed in this study will be Southampton Road Elementary School in Westfield, MA. This school participates in the safe routes to school program and is located next to numbered route roads which have the capacity to carry heavy volumes of traffic. Southampton Road Elementary School is located on Route 202/10, and a half mile from the exit 3 Massachusetts Interstate 90(MassPike). In 2006 Southampton Road north of this interchange carried an annual average daily traffic (AADT) of 18,900 vehicles according to MassDOT's traffic count records. The school entrance is located roughly 60 meters to the Route 20/202, the two back ends of the school are located 143 and 126 meters away, which is well within 150 meter distance studied by Venn, 2001 and Green, 2004(Figure-3). The children who attend this school are also located less than 1000 meters form Barnes Airport. Furthermore a major industrial sector of Westfield, which requires heavy diesel trucks to transport goods. While not included in the study, North Middle School is located behind the to transport goods. While not included in the study, North Middle School is located behind the elementary school. The student who attend this school are exposed to exhaust emissions from a variety of modes of transport. If the school can reduce the amount of trips made by parents, they are proactively reducing their children exposure rates.

This school have regional air quality hurdles to overcome as well to provide optimal environmental conditions. Hampden County has been considered a non attainment zone under the Clean Air Act Amendments of 1990. This designation indicates that the regional air quality exceeds the maximum values allowed under the National Ambient Air Quality Standards. These EPA standards are established to improve and protect human health. These site locations are vulnerable to emissions from vehicular use and pre existing regional challenges

Figure 3-Orthographic Image of Southampton Road School

Image Credit-Pioneer Valley Planning Commission

Blue=143 meters Red=60 Meters Purple=126 meters

How to Further Testing Method

This test method could be aided by calculation of cold start and evaporative emissions produced by vehicles traveling to the school. Cold start emissions could have a large impact due to the nature of trips made to school. Typically these are the first trips of the day, vehicles sit overnight and do not operate as efficiently on its first trip of the day. Once the engine is warm and the engine has been lubricated emissions levels improve due to the increase efficiency. The impact of these cold start emissions are not identified in this study. Faculty trips typically originate at home then travel and park at their school. Faculty produce emissions from cold start emissions and also parking at school which produces evaporative emissions. Emissions evaporate off of the engine and exhaust as it cools down from the trip. Evaporative emissions are not estimated in this study.

A large contributor of emissions generated by schools are the school bus emissions. Due to larger vehicle size, more energy is needed to propel the vehicle, these larger mechanical parts produce more emissions. Diesel engines are used in the majority of school buses which produce more emissions than normal passenger car emissions. School buses emissions were not calculated in this study. This additional information could be utilized to calculate the total amount of emissions generated by all vehicles traveling to school.

Exposure rates traveling to school are not included in this study. The rates of children walking to school, children riding in a bus cabin, and children riding in personal transport are not calculated in the study. Children walking along roadways are vulnerable to inhale pollutants from the vehicles passing by. The close proximity of children to roadways and exhaust emissions allows inhalation of the toxins. Children riding on school buses are exposed to diesel pollutants within the bus cabin. The cabin is composed of the seating area for the children and driver. School bus cabins are not sealed to the same standards as passenger cars allowing for pollutants to infiltrate the seating area. Children riding in these cabins are exposed and inhale these toxins. This cabin exposure is not studied, knowledge of this exposure amount would provide a comprehensive understanding of children exposure during school trips. Lastly, children riding in passenger cars can be exposed to emissions however, as previously noted these cabins have much better sealing techniques.

CHAPTER 5

Analysis of Statistics

Categorization by Emissions Rates and Vehicle Type

Vehicles were categorized by estimated grams per mile and model year to indicate the amount of generated emissions. The EPA has produced emission fact sheets that estimates passenger cars and light duty trucks, SUVs, vans, motorcycles, etc for the years of 2000, 2005 and 2008. These numbers were produced using the Mobile 6 programs. To prevent overestimation of emissions, the vehicles were given conservative estimates(Table-1). Using this method allowed for vehicles to be attributed grams/mile estimations for future year vehicles (e.g. 2003 uses 2005 emissions rates). While the preceding model year may have had slightly higher rates, the difference in actual rate versus the attributed rate is minimal. Surveys that reported model years from 2006 to 2010 may have some slight overestimation. Vehicles from 2009 and 2010 were subjected to the 2008 emissions rates. The EPA has not come out with an updated version of this information since this 2008 paper.

Table 1-Grams/Mile Categorization

Grams/Mile Categorization	
Model Year	Fact Sheet Used
2000 and Earlier	EPA Fact Sheet 2000
2001-2005	EPA Fact Sheet 2005
2005-2010	EPA Fact Sheet 2008

For purposes of applying the correct emissions rates, respondents to the survey were asked for vehicle type information(Passenger Car, SUV/Truck, Motorcycle, other). All of the surveys reported driving a passenger car or a sport utility vehicle/truck/van. Sport utilities, light duty trucks and vans emit pollutants at a higher rate than passenger cars. These vehicles typically have larger engines and chassis which produce more pollutants.

Emission Rates

Carbon dioxide, Nitrogen Oxides and Volatile Organic Compound emission rates per mile were used to calculate the generated emissions by year and motor vehicle type. The EPA fact sheets report these numbers as grams per miles. For increased consistency the numbers were quantified in pounds(lb) per mile. When transferring the EPA rates into the spreadsheets, the grams per mile were converted into pounds per mile using the conversion factor that one gram equals .0022 pounds. Once the numbers were converted, Table-2 was created to apply the correct rates to the appropriate category.

Carbon dioxide per mile rates remained nearly constant between 2005 and 2008 according to these EPA documents. 2005 passenger cars emitted 0.813505 lbs/mile while in 2008 passenger cars emitted 0.812182 lbs/mile. SUV/Trucks and vans saw a minimal increase from 1.12656 lbs/mile in 2005 to 1.13097 lbs/mile in 2008. Notwithstanding, there was marked improvement in rate reduction from 2000 to 2005.

Table 2-Emissions/Mile by Vehicle Type and Year

Emissions/Mile by Vehicle Year and Type							
Passenger Car (g/mile)				SUV/Truck/Van (g/mile)			
Year	CO2	Nox	VOC	Year	CO2	Nox	VOC
2000	415	1.39	1.36	2000	521.6	1.81	1.61
2005	369	0.95	1.36	2005	511	1.22	1.61
2008	368.4	0.693	1.034	2008	513.5	0.95	1.224

According to these EPA reports Nitrogen Oxides rates have reduced consistently from the year 2000 to 2008. This rate was reduced .44 and .59 g/mile between 2000 and 2005 for passenger cars and SUV/Trucks/Vans respectively. Between 2005 and 2008 the rate was reduced .35 and .27 g/mile for passenger cars and SUV/Trucks/Vans respectively. There was a larger reduction between 2000 and 2005 as compared to 2005 to 2008 can be attributed to a longer time period for technological advancement to impact emission rates.

inconsistent results. There should only be a minimal impact on the total estimated emissions due to the minimal number of vehicles reported from before 2000.

Faculty Emissions

21 Faculty responded to the survey. 10 drove passenger vehicles and 11 drove SUV/Truck/Van. Almost all faculty commutes everyday to the school and in this particular survey 20 of 21 drove everyday to the study school. The total emissions generated by faculty can be seen in table-3. This emissions output was based on a 36 week school year. The average teacher commutes 1854 miles per school year. According to the EPA, the average American drives 12000 miles a year, which would mean commuting to work for these teachers would account for just fewer than 16% of their yearly driving. This mileage is much higher than the pupil's vehicle sources, which accounts for the teacher's larger percentage share in total emitted pollutants.

Table 3-Faculty Emissions by Vehicle Type

Vehicle Source	CO2/School Year	NOx/School Year	VOC/School Year
Faculty Passenger Car	8867952	23177	29902
Faculty SUV/Van/Truck	7986687	16827	21965
Grams	16854639	40004	51867
Pounds	37080	88	114

Based off of the reported surveys, an average vehicle for each vehicle type was created (table-4). Averaging together the responses provided a sample of anticipated pollutants emitted during a typical commute by vehicle type. Averaging together the model years and dividing by the total number of vehicle types, an average model year could be determined for the fleet of vehicles. Passenger cars emissions rates would be comparable to 2005 EPA fact sheet and the SUV-Truck and van category would relate to 2008. The daily emissions totals measured in lbs were determined by multiplying the trip distance by the grams emitted per mile. These averages represent what a normal teacher would emit on their commute to the school.

Table 4-Faculty Average Fleet Emissions

Average Fleet Emissions Output						
Source	Year	Distance (miles)	Total # of Vehicles	CO2 Trip Emissions (grams)	Nox Trip Emissions (grams)	VOC Trip Emissions (grams)
Teacher-Passenger Car	2002	12.97	10	4926.64	12.88	16.61
Teacher-SUV-Truck-Van	2006	7.89	11	4043.02	8.52	11.12

The purpose of creating this calculation is to enhance replicability by simplifying the methods of data collection. Once an average vehicle has been established, a simple vehicle count can be conducted to determine the amount of generated emissions. This vehicle data collection of teachers would separately categorize passenger cars and SUV/Trucks/Vans in order to apply the average estimated emissions for the trip. This same procedure can be applied to parent drop offs. A yearly survey would be needed to quantify the average vehicle within the fleet.

According to the survey, teachers commute longer distances than parents and park their vehicles on school grounds. These driving practices produce a variety of pollutants in addition to exhaust emissions. "With today's efficient exhaust emission controls and gasoline formulations, evaporative losses can account, on hot days, for a majority of the total VOC pollution from current model cars. Evaporative emissions occur in several ways: **Hot soak (Cooling Down)** - The engine remains hot for a period of time after the vehicle is turned off, and gasoline evaporation continues when the car is parked while cooling down. **Diurnal Emissions (Emissions while Parked and Engine is Cooling)** - Even when the vehicle is parked for long periods of time, gasoline evaporation occurs as the temperature rises during the day (Automobile Emissions: An Overview, EPA, 2000)."

Parent Drivers of Pupils

84 parent drivers responded to the survey reporting that 61 pupils were transported in passenger vehicles while 22 were transported in SUV/Trucks/Vans (table-5). Nearly all teachers drive to school daily, however, parents have a greater range in the number of days they drive their children to school. 39 out of the 84 pupils were reported to be driven everyday while 19 of the 84 were transported only

daily, however, parents have a greater range in the number of days they drive their children to school. 39 out of the 84 pupils were reported to be driven everyday while 19 of the 84 were transported only once a week. This range shows how much fluctuation occurs in pupil drop off procedures; however, this sample determines the total percentage that each range would possess. Children typically live closer to the schools than their teacher counterparts. On average parents drive 454 miles to the elementary school each year. In comparison, the teachers' share of miles driven to school was 4 times greater. However, due to the number of parent drivers their emissions totals are relatively similar in comparison to the teachers.

Table 5-Parent Driver Emissions by Vehicle Type

Vehicle Source	CO2/School Year	Nox/School Year	VOC/School Year
Pupil Passenger Car	10579638.96	25056.57	35947.84
Pupil SUV/Truck/Van	4607744.40	10613.20	13586.52
Grams	15187383.36	35669.77	49534.36
Pounds	33412.24	78.47	108.98

An average vehicle type was created for parent driven vehicles as well(table-6). As previously mentioned this average vehicle can be used to categorize and count total arriving vehicles. The numbers were calculated with the same method used for teachers. The average distance for these vehicles is again noticeably shorter than the teachers due to children living in closer proximity to the school. Despite the shorter commute, there are a greater total number of parent drivers which increases the total emitted pollutants.

Table 6-Parent Driver Average Emissions

Average Fleet Emissions Output						
Source	Year	Distance (miles)	Total # of Vehicles	CO2 Trip Emissions (grams)	Nox Trip Emissions (grams)	VOC Trip Emissions (grams)
Pupil-Passenger Car	2005	3.65	62	1346.85	3.10	4.48
Pupil-SUV	2004	3.45	22	1769.95	3.91	5.26

Due to parent's shorter commutes, their emissions are subjected to a concept known as "cold starts." Most of these trips would originate at the home and the school would most likely be the first destination. Trips originating at the house are typically subjected to these cold start increased results in higher emissions because the emissions control equipment has not yet reached its optimal operating temperature.

Total Emissions-Passenger Car versus SUV/Truck/Van Emissions

71 of those surveyed reported that they drove a passenger car, representing 68% of the total vehicle fleet. The remaining 33 were reported to fit under the truck/SUV/van category, which accounts for 32% of the vehicle fleet. The total Carbon dioxide emitted was calculated at slightly over 33 tons. Passenger vehicles accounted for 58% of these pollutants while SUV/Trucks and vans accounted for the remaining 42%. These percentage shares show that SUV/trucks and vans contribute a larger share due to the energy needed to operate the vehicle. The SUV/Trucks and vans category accounts for 35% of both nitrogen oxide and volatile organic compound generated by school trips. This percentage share of emissions is only 3% greater than the vehicle fleet share.

Table 7-Vehiclular Emissions by Vehicle Type

Southampton Road School Vehicular Generated Emissions by Vehicle Type			
Vehicle Source	CO2/School Year	NOx/School Year	VOC/School Year
Passenger Car	42785	106	145
SUV/Truck/Van	27708	60	78

These totals seen in table 7 only attribute for the reported numbers. The number of teachers and parent drivers is known to be greater than the 104 respondents. Tables 8 presents emissions expected if there were 10%, 50% or 100% more teachers or parents of pupils driving. This would increase the teacher total to 23, 32, or 42 respectively, while increasing the parent driver total to 91, 125, or 166.

Table 8-Predicted Yearly Fleet Emissions

Pupil Transport Average Fleet Yearly Emissions Multiplied by 10%			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Pupil Passenger Car	25798.69	61.01	90.266
Pupil SUV/Van	11178.33	25.27	34.265
Totals	36977.02	86.29	124.53
Pupil Transport Average Fleet Yearly Emissions Multiplied by 50%			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Pupil Passenger Car	35180.02	83.2	123.09
Pupil SUV/Van	15243.18	34.47	46.725
Totals	50423.2	117.67	169.81
Pupil Transport Average Fleet Yearly Emissions Multiplied by 100%			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Pupil Passenger Car	46906.7	110.94	164.12
Pupil SUV/Van	20324.24	45.96	62.3
Totals	67230.94	156.9	226.42
Teacher Average Fleet Yearly Emissions Multiplied by 10%			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Teacher Passenger Car	16399.36	60.709	93.94
Teacher SUV/Van	19358.51	40.799	54.197
Totals	35757.87	101.5	148.13
Teacher Average Fleet Daily Yearly Multiplied by 50%			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Teacher Passenger Car	22362.76	82.78	128.1
Teacher SUV/Van	26397.97	55.63	73.9
Totals	48760.74	138.42	202
Teacher Average Fleet Daily Yearly Multiplied by 100%			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Teacher Passenger Car	29817.02	110.38	170.8
Teacher SUV/Van	35197.3	74.18	98.54
Totals	65014.32	184.56	269.34

There are more than just 104 parent drivers and teachers who transport themselves to the school. As the two preceding tables display the total emissions on a yearly average can increase dramatically with a higher quantity of drivers. These predictions are based off of the sample and assume that teachers and student vehicle fleet averages would remain similar.

What could carpooling do?

Very few of the survey respondents reported that they carpooled. In fact, 6 of the 104 recorded that they transported another child to the school. These carpools are an essential way to reduce the emissions generated by a school. Providing transportation for another pupil of the school immediately reduces the number of vehicles traveling to the school. A reduction in the total vehicles traveling to school would decrease the overall emitted pollutants. It is assumed for this study that children being carpooled would travel through the same mode (motor vehicle) if not carpooling. Emissions reduction could be attained easily through a carpooling initiative from parents and from the teachers. Carpooling reduces the number of cars needed to transport students to schools and the number of cold start vehicles traveling to the school. Since morning trips usually are the first trip made by the vehicle, the vehicles do not operate as efficiently in turn producing more emissions. Faculty could reduce the amount of evaporative and cold start emissions if there was more carpooling. The cold start emissions would be reduced by reducing the total number of vehicles. Evaporative emissions reduction is linked to the generating fewer faculty motor vehicles that park in close proximity to schools. The study school has very little control or power over the traffic volume on Route 10-202 immediately adjacent to the school. They cannot control the emissions they receive from Barnes Airport or from the Mass Pike. However, the school can promote a reduction in the emissions that they generate. Carpooling may be the most effective method in attaining immediate reduction in emissions. Table 9 displays the saving a 10% or 25% increase in carpooling would decrease total emissions.

Table 9-Emissions Reductions with Increase Rate of Carpooling

Average Fleet Daily Emissions Surveyed Conditions			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Teacher Passenger Car	19509.49	50.99	65.78
Teacher SUV/Van	17570.71	37.02	48.32
Pupil Passenger Car	23275.21	55.12	79.09
Pupil	10137.04	23.35	29.89
Totals	70492.45	166.48	223.08

Average Fleet Daily Emissions 10% Carpool			
Vehicle Source	CO2/School Year (lb)	Nox/School Year (lb)	VOC/School Year (lb)
Teacher Passenger Car	13417.66	49.67	76.86
Teacher	15838.79	33.38	44.35
Pupil Passenger Car	21108.02	49.92	73.86
Pupil SUV/Van	9145.91	20.68	28.03
Totals	59510.37	153.65	223.1

Average Fleet Daily Emissions 25% Carpool			
Vehicle Source	CO2/School	Nox/School	VOC/School
Teacher Passenger Car	11181.38	41.39	64.05
Teacher SUV/Van	13198.99	27.82	36.96
Pupil Passenger Car	17590.02	41.6	61.55
Pupil SUV/Van	7621.59	17.23	23.36
Totals	49591.97	128.04	185.92

Emissions savings can be easily attained through carpool initiatives. Many of these short trips could be accomplished by neighbors with children, and could limit the emitted pollutants to nearby schools. The school has few options to curb the emissions generated by the highway, route 10-202, and Barnes Airport. Teachers may have a harder time arranging for carpools due to the increased distance most travel. A larger range in travel distance typically would mean a larger area of habitation, so trips can not be planned as easily as with the parent drivers.

CHAPTER 5

Conclusions

Application of this equation will enable schools to measure emissions and track daily, weekly, monthly, and for the school year progress quantitatively. The need of quantitative information is necessary for the continuation of the claim of improved air quality and would be an improvement from the assumptions that Safe Routes to School currently claims. This justification will come from the ability to produce a baseline of emissions before initiatives or the program has been implemented and a post implementation study to track the actual emissions reduced. Furthermore, schools and Safe Routes to School will have greater knowledge of the pollutants that are being generated and their contribution to regional air quality problems.

Most importantly this quantitative method will allow for comparison between states, towns, city and towns, and rural and urban areas. This comparison is vital to understand the effectiveness of initiatives implemented in certain geographic areas and built forms (urban, suburban and rural). The calculation will provide a method to determine where certain initiatives work and where they do not work for reduction of emissions generated by the school. A walking school bus may not have the same effectiveness in a suburban town versus a city. A park and walk program may not be applicable in a rural area but is more appropriate in a suburban town. The calculated emissions will establish the ability to determine patterns and what programs work well in specific communities. This knowledge identifies what programs are applicable to these communities for reduction of motor vehicles and their correlating air quality improvements. These specific programs that have been identified will reduce the costs of program implementation by decreasing the amount of energy needed to identify initiatives to implement. This identification will aid in production of best management practices for implementation of determining what individual initiatives will work for the school that has applied. Yearly tracking of the program and post implementation will produce a plethora of data for this type of analysis. This quantitative method removes the current assumption based claim while improving the data available for future application of the Safe Routes to School Program.

CHAPTER 6

Recommendations

New Schools

For schools that are applying for Safe Routes to School it is an ideal time for the calculation to be performed to determine baseline emissions. After program implementation, infrastructure improvement and educational programs the study should be conducted again to assess the amount of emissions reduced. Vehicle counts can be performed monthly and applied to the averages produced by the survey to track monthly progress. The survey should be conducted at the beginning of each survey to produce a new sample to apply for these monthly averages. If a new Safe Routes to school initiative is applied to the school, the survey can be conducted to determine its impact on emissions reduction.

Currently Enrolled Schools

Schools that are already enrolled can use this tool to calculate a starting level of emissions. Emissions reduction can not be expected to be as drastic, as funding for the program has been spent and there is little access to new funding sources. However, progress can still be tracked on a monthly basis as discussed above. Similarly to new school, new Safe Routes to school initiative is applied to the school, the survey can be conducted to determine its impact on emissions reduction.

Safe Routes to School Administrators

Creation of a website can be utilized for schools to track their progress. The website can posses the figures from the EPA fact sheets and users can input the individual survey results. The website can calculate and store these data sets for the school and administrative use. This would create a large amount of data with correlating school information. This school information can be grouped into categories of urban, rural, suburban, city, as Safe Routes to School Administrators see fit. This tool will allow the program to develop patterns and identify the best initiatives for both regions and built forms. Ultimately this collection of data will aid in the determination of best management practices for specific geographic regions and built forms.

Appendix

Figure-1 Speed Emissions Curve

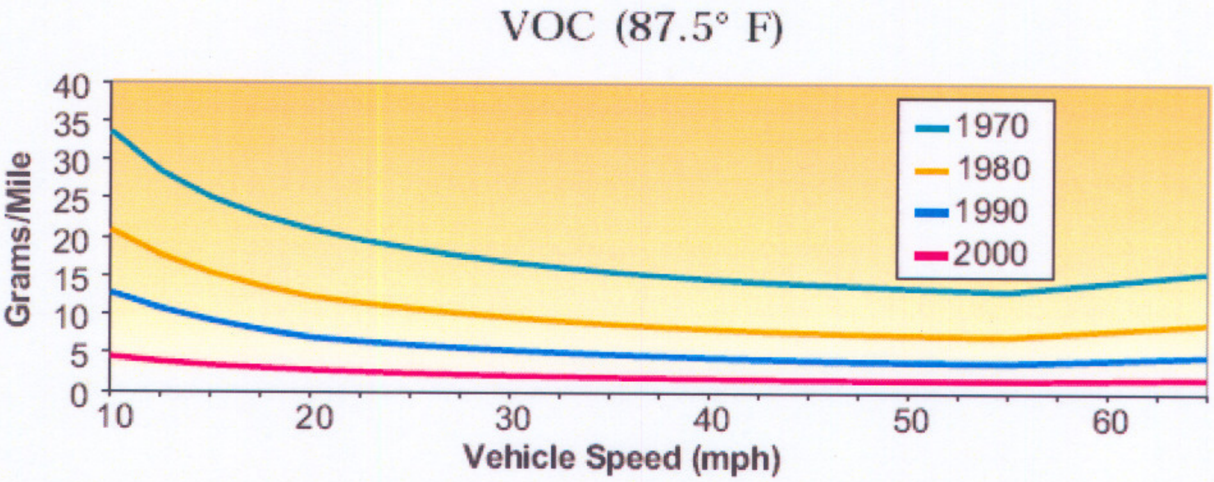

Figure-2

Parent Survey About Walking and Biking to School

Dear Parent or Caregiver,

Your child's school wants to learn your thoughts about children walking and biking to school. This survey will take about 5 - 10 minutes to complete. We ask that each family complete only one survey per school your children attend. If more than one child from a school brings a survey home, please fill out the survey for the child with the next birthday from today's date.

After you have completed this survey, send it back to the school with your child or give it to the teacher. Your responses will be kept confidential and neither your name nor your child's name will be associated with any results.

Thank you for participating in this survey!

+ **CAPITAL LETTERS ONLY – BLUE OR BLACK INK ONLY** +

School Name:

☐☐

1. What is the grade of the child who brought home this survey? ☐☐ Grade (PK,K,1,2,3...)

2. Is the child who brought home this survey male or female? ☐ Male ☐ Female

3. How many children do you have in Kindergarten through 8th grade? ☐☐

4. What is the street intersection nearest your home? (Provide the names of two intersecting streets)

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ **and** ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Place a clear 'X' inside box. If you make a mistake, fill the entire box, and then mark the correct box.

5. How far does your child live from school?

- ☐ Less than ¼ mile
- ☐ ¼ mile up to ½ mile
- ☐ ½ mile up to 1 mile
- ☐ 1 mile up to 2 miles
- ☐ More than 2 miles
- ☐ Don't know

Place a clear 'X' inside box. If you make a mistake, fill the entire box, and then mark the correct box. +

6. On most days, how does your child arrive and leave for school? (Select one choice per column, mark box with X)

Arrive at school

- ☐ Walk
- ☐ Bike
- ☐ School Bus
- ☐ Family vehicle (only children in your family)
- ☐ Carpool (Children from other families)
- ☐ Transit (city bus, subway, etc.)
- ☐ Other (skateboard, scooter, inline skates, etc.)

Leave from school

- ☐ Walk
- ☐ Bike
- ☐ School Bus
- ☐ Family vehicle (only children in your family)
- ☐ Carpool (Children from other families)
- ☐ Transit (city bus, subway, etc.)
- ☐ Other (skateboard, scooter, inline skates, etc.)

+ **Place a clear 'X' inside box. If you make a mistake, fill the entire box, and then mark the correct box** +

7. How long does it normally take your child to get to/from school? (Select one choice per column, mark box with X)

Travel time to school

- ☐ Less than 5 minutes
- ☐ 5 – 10 minutes
- ☐ 11 – 20 minutes
- ☐ More than 20 minutes
- ☐ Don't know / Not sure

Travel time from school

- ☐ Less than 5 minutes
- ☐ 5 – 10 minutes
- ☐ 11 – 20 minutes
- ☐ More than 20 minutes
- ☐ Don't know / Not sure

+ +

Figure-2(continued)

8. **Has your child asked you for permission to walk or bike to/from school in the last year?** ☐ Yes ☐ No

9. **At what grade would you allow your child to walk or bike to/from school without an adult?**

(Select a grade between PK,K,1,2,3...) ☐☐ grade **(or)** ☐ I would not feel comfortable at any grade

Place a clear 'X' inside box. If you make a mistake, fill the entire box, and then mark the correct box

10. **What of the following issues affected your decision to allow, or not allow, your child to walk or bike to/from school?** (Select ALL that apply)

11. **Would you probably let your child walk or bike to/from school if this problem were changed or improved?** (Select one choice per line, mark box with X)

☐ My child already walks or bikes to/from school

10.	11.		
☐ Distance	☐ Yes	☐ No	☐ Not Sure
☐ Convenience of driving	☐ Yes	☐ No	☐ Not Sure
☐ Time	☐ Yes	☐ No	☐ Not Sure
☐ Child's before or after-school activities	☐ Yes	☐ No	☐ Not Sure
☐ Speed of traffic along route	☐ Yes	☐ No	☐ Not Sure
☐ Amount of traffic along route	☐ Yes	☐ No	☐ Not Sure
☐ Adults to walk or bike with	☐ Yes	☐ No	☐ Not Sure
☐ Sidewalks or pathways	☐ Yes	☐ No	☐ Not Sure
☐ Safety of intersections and crossings	☐ Yes	☐ No	☐ Not Sure
☐ Crossing guards	☐ Yes	☐ No	☐ Not Sure
☐ Violence or crime	☐ Yes	☐ No	☐ Not Sure
☐ Weather or climate	☐ Yes	☐ No	☐ Not Sure

Place a clear 'X' inside box. If you make a mistake, fill the entire box, and then mark the correct box

12. **In your opinion, how much does your child's school encourage or discourage walking and biking to/from school?**

☐ Strongly Encourages ☐ Encourages ☐ Neither ☐ Discourages ☐ Strongly Discourages

13. **How much fun is walking or biking to/from school for your child?**

☐ Very Fun ☐ Fun ☐ Neutral ☐ Boring ☐ Very Boring

14. **How healthy is walking or biking to/from school for your child?**

☐ Very Healthy ☐ Healthy ☐ Neutral ☐ Unhealthy ☐ Very Unhealthy

Place a clear 'X' inside box. If you make a mistake, fill the entire box, and then mark the correct box

15. **What is the highest grade or year of school you completed?**

☐ Grades 1 through 8 (Elementary)
☐ Grades 9 through 11 (Some high school)
☐ Grade 12 or GED (High school graduate)
☐ College 1 to 3 years (Some college or technical school)
☐ College 4 years or more (College graduate)
☐ Prefer not to answer

16. **Please provide any additional comments below.**

Figure-3 (Parent Survey and Teacher Survey the Same except Teacher Survey Heading Read:

"Southampton Road Elementary School-Teacher Survey"

Southampton Road Elementary School-Parent Driver Survey

This survey is completely voluntary and there are no requirements to take this survey. Please do not provide names, survey should remain anonymous. The purpose of this survey is to estimate the amount of vehicular emissions that are being generated by your school.

1. What kind of vehicle do you drive (Please circle)? 1) Passenger Car 2) Truck/SUV 3) Motorcycle 4) Other_______________(Please Specify)
2. What model year is your vehicle (i.e. 2004)? ______________
3. Do you carpool on a typical trip to or from school (Please Circle)? 1) No 2) Yes
4. If yes to # 3, how many pupils are in your carpool? __________
5. What is the distance of your typical trip to or from school (to the nearest tenth of a mile, e.g. 3.1 miles)? ___________
6. How many days a week do you typically drive to school (Please Circle)? 1) One Day 2) Two Days 3) Three Days 4) Four Days 5) Everyday

Table-1

Average Distance Traveled to School for Southampton Road Service Area

Location	Miles Traveled to School
Montgomery Street/Notre Dame Street	1.8
Warfield Drive/Root Road	3.1
Russellville Road/Deer Path Lane	4.8
Hawks Circle/Prospect Street Extension	3.8
Springdale Road/Sandy Hill Road	1.6
Montgomery Road/West Road	4
Total Distance	19.1
Average Distance	3.2

[1] http://www.saferoutesinfo.org/legislation_funding/, accessed on April 4th, 2010
[2] United States of America. Surface Transportation Policy Patenership. High Mileage Moms. 2002.
3 Duany, Andres. Suburban nation: The rise and the decline of the American Dream. North Print Press, 2001
4 United States of America. Surface Transportation Policy Patenership. High Mileage Moms. 2002.
5 United States of America. U.S. Department of Transportation Federal Highway Administration. Safe Routes to School National Partnership Consensus Statement
[6] McDonald, Noreen C. and Aalborg, Annette E.(2009) 'Why Parents Drive Children to School: Implications for Safe Routes to School Programs', Journal of the American Planning Association, 75: 3, 331 — 342.
[7] James F. Sallis and Karen Glanz(2006). The Role of Built Enviornments in Physical Activity, Eating and Obesity in Childhood. The Future of Children. 16" 1, 89-108.
[8] Neeta Kulkarni and Jonathan Grigg(2008). Effects of air pollution on children, Pediatrics and Child Health, 18:5, 238-243.
[9] Kulkarni(See above)
[10] Vliet et al(2003). The relationship between air pollution from heavy traffic and allergic sensitizations, bronchial hyperresponsivness, and respiratory systems in Dutch schoolchildren.. Environ Health Perspect, 111:1512-1518.
[11] A Oosterlee, M Drijver, E Lebret, et al(1996). Chronic repiratory symptoms in children and adults living along streets with high traffic density. Occupational and Environmental Medicine, 53:241-247.
[12] Kim et al(2004). Traffic-related Air Pollution near Busy Roads: The East Bay Childrens Respiratory Health Study. American Journal of Respiratory and Critical Care Medicine, 170: 520-526.
[13] Kim(See above)
[14] Vliet(See above)
[15] Oosterlee(See above)
[16] Joseph W. Green and Paul A Zandbergan(2007). Error and Bias in Determining Exposure Potential of Children ar School Locations Using Proximity-Based GIS Techniques, Environmental Health Perspectives, 115:9, 1363-1370.
[17] Venn. et al. *"Living near a main road and the risk of wheezing illness in children."* American Journal of Respiratory and Critical Care Medicine. 2001; Vol.164, pp. 2177-2180.
[18] Venn (See above)
[19] Appatova et. Al. (2008). Primal exposure of public schools and students to major roadways: a nationwide US survey. Journal of Environmental Planning and Management. Vol. 51:5, 631-646.
[20] Atkinson, Roger (2000). Atmospheric chemistry of VOXs and NOx. Atmospheric Environment. VOl. 34, 2063-2101.
[21] McIlveen, R. (1992) Fundamentals of Weather and Climate, second edition, London: Chapman and Hall.
[22] Saunders, S. M., R. G. Derwent, and M. E. Jenkin. "Photochemical Ozone Creation Potential for a Large Number of Reactive Hydrocarbons under under European Condtionas." Atmospheric Environment30.2 (1996): 181-99
[23] Atkinson(See above)
24 Sjaak Slanina (Lead Author); Howard Hanson (Topic Editor);. 2006. "Impact of ozone on climate change." In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published in the Encyclopedia of Earth September 20, 2006; Last revised November 30, 2006; Retrieved August 22,
[25] United States of America. Environmental Protection Agency. Control Emmissions Technologies - Transport & Dispersion of Air Pollutants. 29 Jan. 2010. Web. 15 Apr. 2010. <http://www.epa.gov/apti/course422/ce1.html
[26] EPA, Transport & Dispersion of Air Pollutants.(See above)
[27] United States of America. Environmental Protection Agency. An Introduction to Indoor Air Quality. 23 Apr. 2010. Web. 20 May 2010. <http://www.epa.gov/iaq/voc.html>
[28] Mendell M. J. (2007). Indoor residential chemical emissions as risk factors for respiratory and allergic effects in children: A review. Indoor Air, 17(4), 259-277.
[29] EPA, Transport & Dispersion of Air Pollutants.(See above)
[30] Kleinmann(2000). South Coast Air Quality Management District: The Health Effects of Air Pollution on Children.
[31] Environmental Protection Agency. An Introduction to Indoor Air Quality
[32] United States of America. Environmental Protection Agency. 2010 U.S. Greenhouse Gas Inventory Report. 2010.
[33] United States of America. Environmental Protection Agency. Human-Related Sources and Sinks of Carbon Dioxide. 14 July 2010. Web. 15 Apr. 2010. <http://www.epa.gov/climatechange/emissions/co2_human.html>
[34] United States of America. Minnesota Department of Health. Carbon Monoxide (CO) Poisoning in Your Home. Web. 15 Apr. 2010. <http://www.health.state.mn.us/divs/eh/indoorair/co/index.html
[35] United States of America. Environmental Protection Agency. Office of Air Quality Planning and Standards. Technical Bulletin: Nitrogen Oxides (NOx) Why and How They Are Controlled. Vol. EPA Form 2220-1. 1999. Print
[36] EPA. Human-Related Sources and Sinks of Carbon Dioxide(See above)
[37] Kleinmann (see above)

[38] EPA. Human-Related Sources and Sinks of Carbon Dioxide(See above

[39] Kleinmann (see above)

[40] United States of America. Environmental Protection Agency. 2010 U.S. Greenhouse Gas Inventory Report. 2010.

[41] Chen(See above)

[42] United Kingdom. Department of Transport. Low Carbon Transport: A Greener Future. 2009.

[43] American Bus Association. Comparison of Energy Use & CO2 Emissions From Different Transportation Modes. 2007.

[44] United States of America. U.S. Department of Transportation Federal Highway Administration. Safe Routes to School. State SRTS Contacts. Web. 15 Apr. 2010. <http://www.saferoutesinfo.org/contacts/index.cfm

[45] Hubsmith, Deb. "Recommendations for the 2010 Federal Transportation Bill: Improving Pedestrian and Bicycle Safety Can Create Safe and Livable Communities All Across America." Reauthorization Outreach Meeting. California, Los Angeles. 12 Mar. 2010. Lecture

[46] Weigand, Lynn. "The Effectiveness of Safe Routes to School and Other Programs to Promote Active Transportation to School." Review. Initiative for Bicycle and Pedestrian Innovation June 2008. Print.

[47] Mcdonald and Aalborg (See above)

[47] Mcdonald and Aalborg (See above)

[47] Emission Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks. Rep. no. EPA420-F-00-013. Print